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EFFECT OF HIGH-CARBON COMPONENTS AND OTHER ADDITIVES UPON CHARACTER OF COKES: LABORATORY SCALE STUDY

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INTRODUCTION

A high percentage of metallurgical coke is produced by blending at least two coals in order to make a coke having the desired physical properties. A number of laboratories, some with pilot plant coking facilities, are conducting investigations in which various coal blends that contain marginal coking coal are being tested. As reserves of coal, now considered as good coking coal, continue to decrease, it will be necessary to know how best to use the marginal coking coals to meet the demands for good metallurgical coke.

Laboratory investigations at the Illinois State Geological Survey have indicated that the petrographic composition of the coal charge definitely affects the coke. One aspect of the laboratory investigation that has been tested on a limited basis in the pilot plant is the alteration of the petrographic composition of the coal charge by increasing the amount of high-carbon coal component fusain. Although direct correlation between the laboratory and pilot plant scale tests was not made, the trends established in tumbler and shatter tests of cokes made in the laboratory were generally the same as those from the larger scale tests, and in each case certain physical properties of the resulting coke were improved with the addition of an optimum amount of fusain.

The present study is concerned with the influence upon the physical properties of coke produced by blending coal with one of the components. These components or additives varied in amounts and size and some additives contained a high percentage of carbon. Laboratory scale coke tests on blends of No. 6 and No. 5 Coals established on optimum coal blend that was used as a "standard blend" to which the high-carbon components were added. Materials added to the "standard blend" are referred to subsequently as additives. Trends established in these laboratory studies in which the petrographic composition of the coal charge was closely controlled provide a basis for pilot scale tests.

PROCEDURES

Coal Samples; Collection and Selection

Channel samples, six inches wide and four inches deep, were cut from fresh coal faces of No. 6 Coal in Jefferson County, and from No. 5 Coal in Saline County. Large bands of mineral matter was removed and the samples were sealed in air-tight cans in the mine to minimize oxidation of the coal.

Previous studies (Marshall et al., 1958) demonstrated that a method of crushing, achieved by progressive screening and crushing to prevent overcrushing of fine size, yielded optimum physical properties in the coke produced from No. 6 and No. 5 coals on a laboratory scale. The same crushing procedure was adapted for the present study. This procedure reduced all the sample to minus 1/8-inch except for 0.2 or 0.3 percent which consisted predominantly of shale and dull coal.

The resulting sample was considered as standard and had constant size consist as determined by screen analysis. The size analysis of both No. 6 and No. 5 coal is essentially the same.

Additives; Collection and Selection

Additives used in this investigation were fusain, anthracite, coke dust, coke breeze, petroleum coke, minus 48-mesh coal from a preparation plant, black shale and the blend of No. 6 and No. 5 Coals reduced to three size fractions smaller than the standard size fraction.

Lenses of almost pure fusain four to five inches thick were handpicked, dried, and screened through a minus 150-mesh screen without crushing. Hard mineral-bearing fusain was retained on a 20-mesh screen. The screen analysis of the minus 150-mesh fusain demonstrates that the natural breakage of the material is 92.9 percent minus 270-mesh.

Three sized samples of anthracite were prepared, namely: minus 10-mesh, minus 20-mesh, and minus 150-mesh (the latter had approximately the same size consist as the minus 150-mesh fusain, fig. 1). Anthracite was first crushed by duplicating the crushing procedures used for No. 6 and No. 5 coals. The sample was divided into three equal fractions, one for each size fraction. The minus 10-mesh sample was prepared by passing the anthracite three times through the rolls set at 1/8 inch. After each crushing the minus 10-mesh material was screened out to prevent additional crushing of the fine sizes. It was necessary to set the rolls of the crusher at 1/20 inch in the preparation of the minus 20-mesh anthracite, which was also crushed and progressively screened three times. To secure the high percentage of minus 270-mesh material, comparable to that in the fusain, it was necessary alternately to hand grind and screen the anthracite until the desired size consist was reached.

Coke dust and coke breeze for this investigation was taken from the Survey's pilot plant oven. Coke dust was derived from the samples used in tumbler tests and the material was all minus 20-mesh. The minus 150-mesh sample was obtained by hand grinding and progressive screening. Two size fractions, 6 x 10-mesh and minus 10-mesh were screened from the coke breeze. It was necessary to pass the coke breeze through the rolls set at 1/20 inch to obtain the minus 20-mesh coke breeze sample. No minus 150-mesh coke breeze was used in the tests.

The petroleum coke had been previously crushed when furnished to our laboratory. Only the minus 10- and minus 20-mesh fractions were screened from this material for use in coking tests.

The minus 48-mesh coal was added to the coke charge without additional screening in hopes that improvements could be made in the physical properties of coke with minimum preparation.

A sample of black shale was collected from over the No. 5 coal in Fulton County, Illinois, and prepared in the same manner as the anthracite in minus 10-mesh, minus 20-mesh, and minus 150-mesh size fractions.

The minus 10-mesh, minus 20-mesh, and the minus 150-mesh size fractions of the "standard blend" of No. 6 and No. 5 Coals were obtained by first screening the standard size samples to produce the minus 10-mesh size. The oversize was crushed and screened for the minus 20-mesh fraction, and oversize was recrushed to produce the minus 150-mesh size consist.

Petrographic and Shape Examination, Analysis and Assessment

Petrographic analyses of broken coal samples were determined by the point count method. (See Marshall et al., 1958, for methods of sample preparation.)

For this investigation macerals were designated as vitrinite, exinite, semi-fusinite, and inertinite. Vitrinite is a group term which included all vitrain with the lower limit imposed by the resolving power of the microscope, humic degradation matter, resin rodlets, and resins classified as red resins in transmitted light studies. All spore coats, cuticles, and yellow resins were considered as exinite. Semi-fusinite consisted of the material intermediate between vitrinite and fusinite. Under the term inertinite were grouped the macerals known as fusinite, micrinite, and a material that resembled sclerotinite. Visible mineral matter was also determined.

All petrographic analyses were made with an oil objective at a magnification of 320 diameters.

Shape analyses were made with the same microscope but with an optical system using a dry objective which gave a magnification of 128 diameters. Criterion established for the shape analysis placed individual coal particles in one of five categories, equi-dimensional, elongate, rodlike, triangular, and angular.

Chemical Analyses

Proximate analyses were made on all samples. Gieseler fluidity and Free Swelling Index determinations also were made on all samples which developed plasticity.

Coke Production

In an earlier investigation by Marshall et al. (1959), the furnace used for coke production, the charging temperature, rate of heating, final temperature, and the final coking period were investigated thoroughly and reported in detail. For this report a brief discussion of the oven and crucible used, along with optimum coking temperatures, will suffice.

The oven is a Harper Globar type furnace (pl. 1) with thermostatic controls. With the addition of a flue, a series of closely adjustable dampers, and an exhaust system for removal of volatiles, this furnace gave excellent service.

The crucibles were thin-walled alumina, cylindrical, three inches in diameter and approximately six inches in height, in which coal charges of 300 to 400 grams could be coked conveniently. Fireclay covers and bases were used to protect the charge and the crucibles.

Each coke run was made in triplicate, and as the oven would hold nine crucibles, three different coke runs were undertaken each time the furnace was heated. The furnace was charged at a temperature of 842°F (450°C). Temperatures were increased at the rate of 6.5°F per minute (3.6°C. per minute) until it attained 1850°F (1010°C), at which point a constant temperature was maintained for a two-hour period.

Upon removal from the furnace the contents of each crucible were quickly quenched in individual water baths, then removed from the water, placed in individual pans, and dried for two days on the furnace top.

Coke Tests

Two of the methods of testing developed in the previous study by Marshall et al., (1958) were used. These were modifications of ASTM shatter and tumbler procedures in which it was hoped that the results would show trends similar to those shown by the standard methods of testing. Limited tests - three which considered size consist of the coal charge and three in which the amount of fusain was varied - indicated that laboratory test cokes showed physical properties similar to those shown by pilot plant cokes, although the absolute values of shatter and tumbler indices differ in magnitude.

Present day industrial evaluation of the physical properties of coke indicates that blast furnace behavior is more nearly characterized by tumbler tests than by shatter tests. Therefore two samples of each coke run were subjected to the tumbler tests and one to the shatter test.

The tumbler test was made by placing the coke sample in a 1/2 gallon metal can, and rotating the can, end over end, for 40 minutes at the rate of 40 revolutions per minute.

The stability index was measured by the tumbler plus 1-inch percentage, and the resistance to abrasion (hardness) was measured by the tumbler plus 1/4 inch fraction. For this investigation the minus 1/4 inch index was plotted as this reflects more clearly the hardness character of the coke. The plus 1-inch fraction from the shatter test was considered a basis for a shatter index. Percentage data on plus 1/4 and minus 1/4 fractions also have been plotted.

It is realized that the modified shatter and tumbler tests used in this investigation, like the standard ASTM tests, are highly emperical and must not be thought of as giving precise results. Test results which differ by small amounts are probably not significant, and a strict comparative evaluation of cokes on the basis of small differences in shatter and tumbler indices is not intended.

STUDY RESULTS

Effect of Blending No. 6 and No. 5 Coals in Various Amounts

For a standard blend, with which various sizes and amounts of additives were to be combined, Illinois No. 6 and No. 5 Coals were blended. To obtain as nearly an optimum blend as possible, eight mixtures of the standard size fractions of No. 6 and No. 5 Coals were coked.

Coal mixtures in this series varied, in 10 percent increments, from a blend of 90 percent No. 6 Coal and 10 percent No. 5 Coal; to 30 percent No. 6 Coal and 70 percent No. 5 Coal. One run of 100 percent No. 6 Coal also was made. Variations in the physical properties of the resulting coke were not great in this series (fig. 2). In evaluating these data tumbler indices were considered more important than shatter indices. Nevertheless, shatter values were not disregarded, and in some instances, when the tumbler indices of two cokes were essentially equal, the shatter indices were used as the deciding factor as to which coke was the better.

Optimum condition for shatter index was found in the 90 percent No. 6 - 10 percent No. 5 Coal blend with 95.3 percent of the coke larger than 1 inch and 97.0 percent larger than 1/4 inch. The lowest of the tumbler minus 1/4-inch indices 9.5 which is desirable, was produced by the blend of 40 percent No. 6 - 60 percent No. 5 Coal. The highest tumbler plus 1-inch index occurred in the blend of 70 percent

No. 6 - 30 percent No. 5 Coal, which appeared to be optimum of the blends when all tumbler and shatter indices were considered. An additional run using the blend of 70 percent No. 6 - 30 percent No. 5 Coal not only showed the reproducibility of the testing, but also sustained the fact that this blend was the optimum. Therefore in all subsequent coke runs, which included additives, the No. 6 and No. 5 proportions were recalculated so that "standard blend" plus additive totaled 100 percent. All subsequent comparisons relative to the "standard blend" refer to both shatter and tumbler indices obtained in testing coke produced from the blend of 70 percent No. 6 - 30 percent No. 5 Coal.

Petrographic analysis of No. 6 and No. 5 Coals was essentially the same (fig. 2). The maximum variation of two percent was found in the exinite; 8.3 percent in No. 6 Coal and 6.3 percent in No. 5 Coal.

Results of screen analysis of the standard samples of No. 6 and No. 5 Coals showed that the breakage produced very nearly the same size consist in both coals.

Chemical analysis of both No. 6 and No. 5 coal samples were made. Gieseler fluidity for both coals is low; No. 6 coal had a maximum fluidity of 3 dial divisions per minute and the No. 5 coal had 29 dial divisions per minute.

Effect of Fusain Additive

Recent studies, both laboratory and pilot plant, have indicated that addition of fusain in an optimum amount to the coal generally improves the physical properties of the resulting coke. In this investigation five, ten, fifteen and twenty percent minus 150 mesh fusain was mixed with the standard 70-30 blend of No. 6 and No. 5 coals.

For reasons undetermined the tumbler plus 1 inch index decreased below that of the "standard blend" with addition of 5 percent minus 150 mesh fusain, but rose to an optimum high of 90.2 when 10 percent fusain was added. The tumbler minus 1/4 inch responded accordingly with an optimum low of 9.4 with 10 percent added fusain. The shatter plus 1 inch rose to its optimum of 95.1 with addition of 5 percent minus 150 mesh fusain and declined steadily thereafter. As fusain has no fusion properties of its own, when an excessive amount is present which cannot be incorporated by the vitrinite and other macerals in the softening period of carbonization, weaker areas occur within the coke. This is strikingly demonstrated as 15 percent fusain is added to the coal charge. With the addition of 20 percent fusain, all indices of the resulting coke deteriorated.

As natural breakage of relatively pure fusain produces a size of minus 150-mesh it is impossible to obtain larger sizes for blending. Larger sizes result from mineralization of the fusain. A 20 x 150-mesh size fusain was obtained and blended with the "standard blend," but this fusain was highly mineralized.

Effect of Anthracite Additive

Blending of anthracite with coal for production of metallurgical coke is not new, but results vary, and, therefore, during this investigation, the effect of amount and size of the anthracite blended with Illinois coals was studied. As previously stated three sized samples of anthracite were prepared, namely minus 150-mesh, minus 20-mesh, and minus 10-mesh. Each size was blended with the "standard blend" in amounts of 5, 10, 15, and 20 percent.

Addition of minus 150-mesh anthracite to the "standard blend" produced cokes whose shatter and tumbler indices were not as good as those of the "standard blend." It was interesting to note that addition of 5 percent minus 150-mesh anthracite had an effect similar to that of adding the same quantity of fusain. The tumbler plus 1-inch and minus 1/4-mesh as well as the shatter plus 1-inch indices indicated a coke of poorer quality than that produced from the "standard blend" alone. The blending of 10 percent minus 150-mesh anthracite produced an improvement, but not to the same extent as that with the fusain blend. Addition of 15 and 20 percent minus 150-mesh anthracite resulted in cokes whose indices decreased greatly.

When the minus 20-mesh sample of anthracite was blended the effect on coke values was different. All tumbler indices improved with the blending of 5 percent of this anthracite and addition of 10 percent produced one of the best cokes made from any blend which included only coal and high-carbon components. The tumbler plus 1-inch index rose to 90.6 and tumbler minus 1/4-inch index fell to 8.4. The tumbler plus 1-inch dropped to 84.7 when 15 percent was added, but instead of continuing to decline as in previous tests with minus 150-mesh anthracite and fusain, this index rose to 86.6 or 1.4 above the "standard blend" for this index. The tumbler minus 1/4-inch index also rose, instead of declining, to 12.6 or 1 above that of the standard blend." All shatter test indices declined slightly.

Shatter and tumbler indices derived from cokes produced from blends of minus 10-mesh anthracite gave results similar to those produced from blends of minus 20-mesh anthracite. Optimum results were obtained with the blending of 10 percent minus 10-mesh anthracite, but the amount of the tumbler plus 1-inch coke was not as great, nor the amount of tumbler minus 1/4-inch coke as small in this optimum as corresponding values obtained with the minus 20-mesh anthracite.

Effect of Coke Dust Additives

Coke dust was acquired from coke used in the tumbler test apparatus at the pilot plant of the Survey and consequently all coke dust was smaller than 20-mesh.

Five percent minus 150-mesh coke dust mixed with the "standard blend" improved the tumbler indices of the resulting coke, but all coke qualities declined as additional minus 150-mesh coke dust was added.

As in anthracite, optimum results were obtained with coke dust by blending the minus 20-mesh material with the "standard blend." The blend of 5 percent minus 20-mesh coke dust resulted in a slight increase in the tumbler index for plus 1-inch, but all other indices were the same or showed a slight decline from the "standard blend." All tumbler values increased to an optimum with the blend of 10 percent minus 20-mesh coke dust, and all indices declined with additional coke dust. Coke dust minus 20-mesh and anthracite minus 20-mesh gave essentially the same optimum results in the 10 percent blend.

Effect of Coke Breeze Additives

Of the three size fractions of coke breeze added, minus 20-mesh, minus 10-mesh, and 6 x 10-mesh, none produced coke having all physical properties better or equivalent to the "standard blend" cokes. The tumbler indices of cokes produced from the blend containing minus 20-mesh coke breeze remained relatively high through the 10 percent blend, but the 1-inch index plunged from 79.9 to 58.4 when 15 percent coke breeze was added.

Optimum coke from this series was produced from blends with 5 percent minus 10-mesh coke breeze; the index for tumbler plus 1-inch increased slightly, giving a higher value than the "standard blend," but all other indices declined. With 10 percent minus 10-mesh breeze the tumbler plus 1 inch dropped from 86.4 to 79.9; with 15 percent breeze this index decreased to 58.4.

Drastic deterioration in coke character was produced by mixing the "standard blend" with 6 x 10 mesh coke breeze. Although the coke remained in one piece upon being discharged from the crucible, and the shrinkage appeared to be slight, the tumbler + 1 inch index was only 40 and the shatter + 1 inch index was only 60.4. Blending of 10 percent 6 x 10 coke breeze caused a further drop in tumbler + 1 inch index to 16 and in the shatter + 1-inch index to 47.6.

Effect of Petroleum Coke Additive

A blend containing 5 percent minus 10-mesh petroleum coke produced optimum coke characteristics in this series. The indices for tumbler plus 1-inch and tumbler minus 1/4 inch were generally comparable with coke produced from 10 percent minus 10-mesh anthracite, (fig. 3), and both were superior to coke produced from the "standard blend." All indices remained relatively high in the petroleum coke blends, both minus 10-mesh (fig. 3) and minus 20-mesh (fig. 4) and did not show the large declines as observed with the coke breeze additive.

Effect of "Fine Coal" Additive

To compare the relative effect on coke of reduced sizes of the coal itself and the relatively high-carbon additives, a sample of the 70 percent No. 6 Coal -30 percent No. 5 Coal was reduced to sizes comparable to those of the high-carbon components, minus 150-mesh, minus 20-mesh and minus 10-mesh size fractions and substituted for them in coal blends for laboratory tests. Physical properties of cokes obtained from blending fine coal with the "standard blend" were closely related to the physical properties of cokes produced by blending various percentages of No. 6 and No. 5 Coals, except for two tests. In these the tumbler indices showed an improvement when 5 and 10 percent of the minus 20-mesh fine coal was used; an increase in inertinite occured in this minus 20-mesh fraction.

Black Shale Additive

In hopes of finding some other natural substance to replace the high-carbon components, black petroliferous shale from above the No. 5 Coal was obtained from a strip mine in western Illinois. A high-ash content was expected but a low total sulfur was hoped for. Analysis shows an ash of 60.2 percent and a total sulfur of 1.52 percent on the "as received" basis. The black shale was prepared in three size fractions, minus 150-, minus 20- and minus 10-mesh, and amounts of 2.5, 5, 7.5, and 10 percent were blended with the "standard blend' of No. 6 and No. 5 Coals. None of the cokes produced from mixtures of minus 150-mesh black shale or minus 10-mesh black shale with the "standard blend" had tumbler and shatter indices equal to those of the "standard blend" when coked alone.

The only black shale size fraction that produced a better coke than that of the "standard blend" was the minus 20-mesh size blended in the amount of 5 percent.

Effect of Minus 48-mesh Coal

Minus 48-mesh coal had previously been considered as a source of a high concentration of fusain. Unfortunately, petrographic analyses of this material exhibited an inertinite (includes fusain) content of only 13.2 percent. The remaining 86.5 percent was composed of 79.6 percent vitrinite, 3.4 percent exinite and 3.8 percent visible mineral matter.

Tumbler and shatter indices of the coke produced by blending this minus 48-mesh coal were deleterious except for the 5 percent blend. In this coke the indices for tumbler plus 1-inch, shatter plus 1/4-inch, and the shatter minus 1/4-inch showed a slight improvement. Although this trend was slight it warrants additional consideration in future testing.

Effect of "Resin" or "Asphaltine" Additive

The previous study by Marshall et al. (1958) demonstrated that a benzene soluble, petroleum ether insoluble, extract of coal tar pitch (termed "resin" or "asphaltene"), when added to a blend of coal and fusain, markedly improved the quality of laboratory cokes produced.

For this latest investigation "resin" was added to those mixtures of additives and "standard blend" which gave optimum coke results. In blends not containing "resin" calculations were made so that the "standard blend" plus the additive equaled 100 percent. In these tests the same calculations were used and 5 percent additional "resin" was added to this blend. The results of these tests are shown in figure 5. Parenthesis around the run number indicates that the coke quality of that run is better than coke produced with the "standard blend."

Run 25A demonstrates that coke quality is improved by addition of "resin" to the "standard blend," but a decided increase in coke quality is produced when 10 percent minus 150-mesh fusain is included in the blend (Run 25B). Tumbler index plus 1-inch increased from 85.2 for the "standard blend" to 93.5 and the index for tumbler minus 1/4-inch decreased from 11.9 to 6.3. Additional fusain in the blend caused deterioration of all cokes, as shown in Figure 5.

Twenty percent minus 20-mesh anthracite was needed in the "resin" and "standard blend" mixture for the optimum coke in the anthracite series (Run 26F). The tumbler index for plus 1-inch was 91.7 and for minus 1/4-inch was 8.3. Addition of 5 percent resin to optimum blends of coke dust or petroleum coke was detrimental, and coke qualities declined below those of the coke produced from the "standard blend."

FACTORS WHICH POSSIBLY AFFECT COKING RESULTS WHEN ADDITIVES ARE USED

Nature of the Additive

A few of the factors that can possibly affect the quality of coke produced by the addition of high-carbon components are considered. The nature of the additive is obviously an important factor. A totally inert substance does not shrink but expands slightly upon heating, and therefore the shrinkage of the mixture is reduced and thus fracturing is reduced. From this, it can be concluded that the temperature at which maximum expansion occurs is important because if maximum expansion occurs after resolidification of the main mass, fractures will form that will weaken the coke. A study of the possible different expansion temperature of high-carbon components used in this investigation was not investigated but should be considered.

The ability of the surface of the additive to absorb the fluid products derived from heating the coal will affect the coking capacity of the charge. It is probable that this ability varies in the additives used in this investigation.

Shape of Individual Particles of Additive

An attempt to evaluate the effect of the shape of individual particles upon coke character did not produce a clean-cut correlation, but two observations were made. The shapes adopted for this classification, as previously mentioned, were equidimension, elongate, rod-like, triangular, and angular. In all shape analyses, the majority of particles were classified as either elongate or rod-like.

The shape of particles in the minus 150-mesh fusain was predominantly rod-like, 79.6 percent, and this component produced the optimum coke, as compared to other additives, in the same size range. Considering only this size fraction, the fusain had a larger surface area than the other additives. Figure 3 shows that most additives produce optimum coke from the minus 20-mesh size. It may be possible that an optimum surface area for an individual particle is necessary for an optimum coke.

The second observation resulted from the comparison of the shape analysis of the coke dust and coke breeze. In the latter, which produced an inferior coke, the percentage of angular particles were higher, 15.8 percent as compared to 3.8 percent for the coke dust.

Amount of Additive

A direct relation between the amount of the additive and coke quality is shown in figures 3, 4, and 6, which show optimum coke indices for each additive in each particular size category. For some components the variation of 5 percent produces marked changes in shatter and tumbler indices (see fusain column in fig. 6). Anthracite in the minus 10-mesh fraction (fig. 3) and coke dust in the minus 20-mesh fraction (fig. 4) demonstrate variations with somewhat less magnitude. Marked deteriorations are produced when the minus 20-mesh and minus 10-mesh fractions of coke breeze are increased from 10 to 15 percent. Marked deteriorations are also shown for black shale minus 150-mesh, anthracite minus 150-mesh, and fusain minus 150-mesh when the amount of each component was increased from 10 to 15 percent.

Particle Size of Additive

The effect of the particle size of the additive upon coke is clearly seen by combined study of figures 3, 4, and 6. Each figure represents coke data produced by blending various amounts of the additives of different size range with the "standard blend." Parentheses have been placed around the percentage figure, at the bottom of each chart, to identify those blends which produced cokes having better physical properties than the coke produced from the "standard blend" alone. These are referred to as "improved cokes."

Only fusain in the minus 150-mesh size range produced improved coke, but three blends of minus 10-mesh material, two anthracite, and one petroleum coke produced this improved coke. Seven blends of minus 20-mesh material, coke dust 10 and 15 percent, anthracite 5 and 10 percent, fine coal 5 and 10 percent, and black shale 5 percent produced improved coke.

The amount of additive, the size of its particles, and the nature of the material appear to be interrelated. For anthracite, 10 percent additive is required for the optimum coke in each size range tested, and in each produced an improved coke. Blends containing 5 percent additives were optimum for black shale and petroleum coke in all size fractions tested, and of these only the black shale minus 20-mesh and petroleum coke minus 10-mesh gave improved cokes. For fine coal, optimum coke was obtained with 5 percent minus 20-mesh and 5 percent minus 150-mesh material added, but in the minus 10-mesh material 15 percent additive was necessary for the most favorable coke indices. Two blends, the minus 20-mesh fraction in 5 and 10 percent amounts produced an improved coke. Five percent minus 10-mesh coke breeze was optimum in this series, but for the minus 20-mesh fraction no amount proved to be optimum for any one blend, as both 5 and 10 percent additive gave about the same over-all results. When coke dust was used as an additive, 10 percent of the minus 20-mesh size consist was optimum and produced an improved coke, but in the minus 150-mesh size consist only 5 percent additive was needed for the optimum coke.

Variation in the Size Consist

An attempt was made to correlate the amount of additive needed, for an optimum coke, with the distribution of the size of the material within each size consist prepared, but it was not possible to make direct correlations using available information.

Blends that Produced an Improved Coke

Figures 7 and 8 show physical properties of 16 improved cokes produced from blends of various additives and the "standard blend" of No. 6 and No. 5 Coals. All additives tested are represented here except coke breeze and minus 48-mesh coal. The best cokes, as evaluated by laboratory shatter and tumbler tests, resulted from blends of coal, anthracite, or fusain, and "resin." Coke derived from coal and coke dust, anthracite, or fusain had physical properties almost as good as those mentioned above. These figures also demonstrate the effect of size and amount of additive upon the coke produced.

CONCLUSION

Physical properties of coke produced from Illinois coals, on a laboratory scale, can be improved by altering the petrographic composition with the addition of high-carbon and other components. Character of the coke produced from these blends depends upon a number of factors among which are the petrographic composition and size of the coal. The surface character, expansion characteristics, chemical composition, amount, particle size, and possibly the shape of the material added are factors that also should be considered.

It has been shown that a certain amount of additive is needed to produce optimum coke indices with each size fraction of additive, but this amount may be different for the different size fractions of the same additive and may vary for different materials added.

From these data we can conclude that blending additives with a coal charge to produce optimum coke is not a haphazard process. Many factors must be considered and each evaluated for optimum conditions to obtain the most favorable shatter and tumbler indices in a coke produced from any one blend.

A logical continuation of this investigation would be on a pilot scale to determine if tendencies as indicated on the laboratory scale would hold true in tests on the larger scale. It is recognized that certain problems exist, such as securing a homogeneous mixture in a 700-pound charge if the sizes of the coal and the additive vary greatly. Preventing segregation in handling the mixture and charging the furnace is important.

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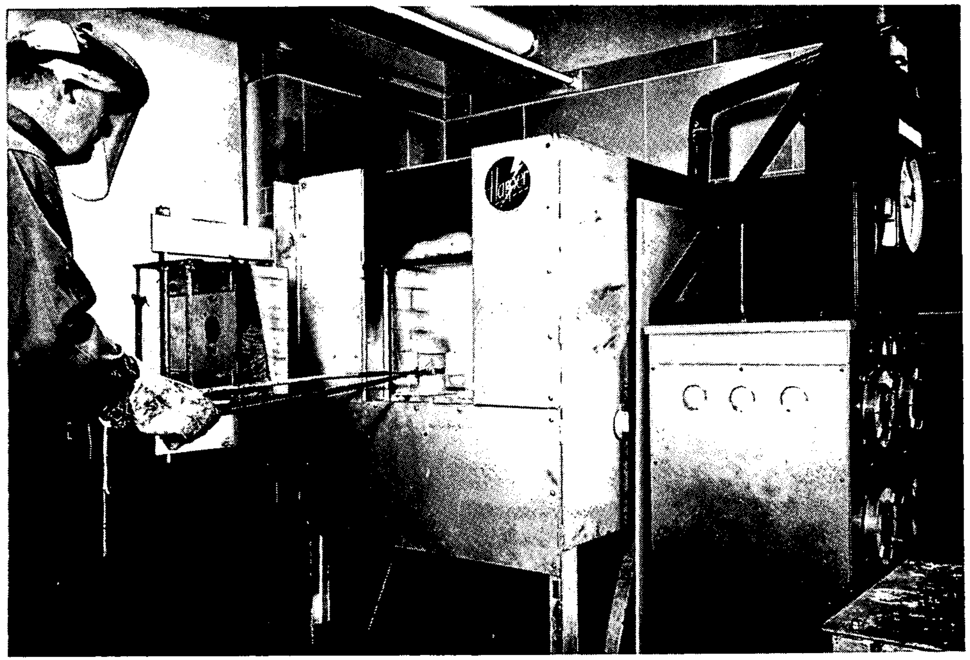


Plate 1. - Charging alumina crucible with fireclay cover and base into furnace used for laboratory coking tests.

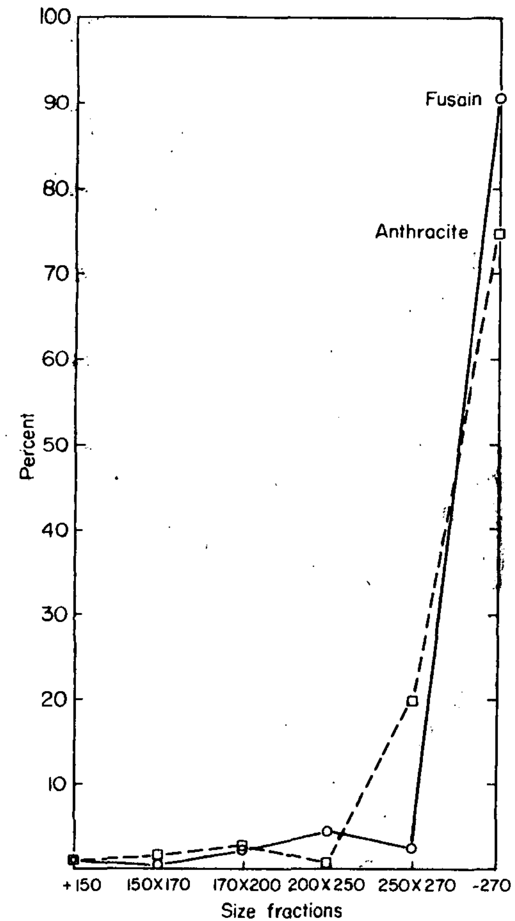


Fig. 1. – Screen analysis of minus 150 mesh fusain and anthracite

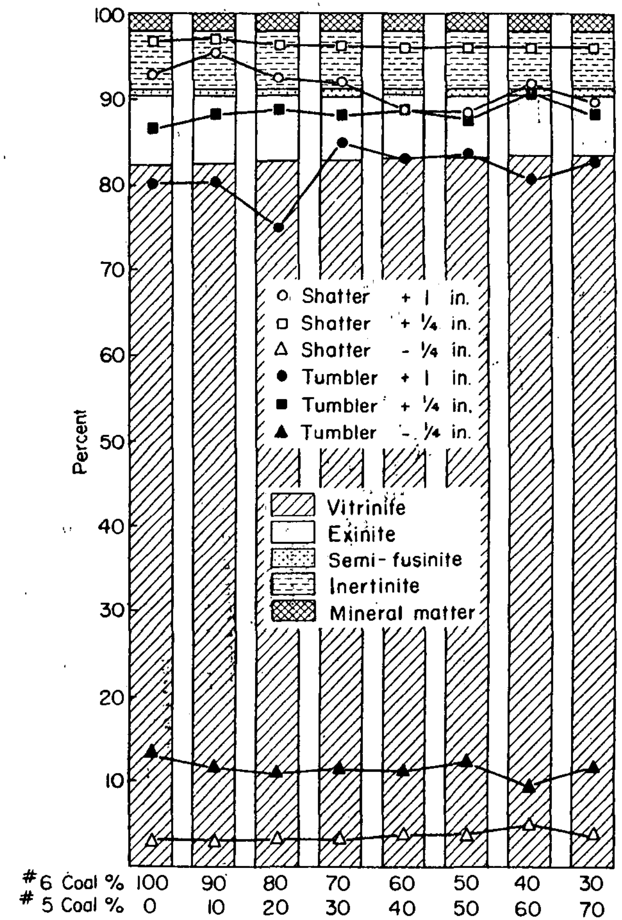


Fig. 2. – Petrographic analysis and character of coke produced from different blends of No. 6 and No. 5 Coals of standard size consist.

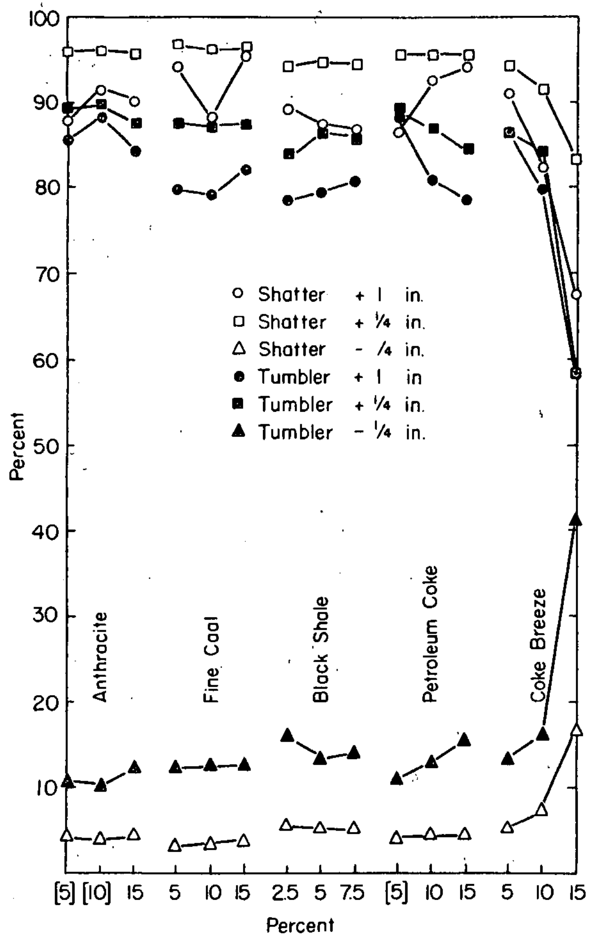


Fig. 3. - Comparison of coke character and the amount of minus 10 mesh material used in blends of different additives.

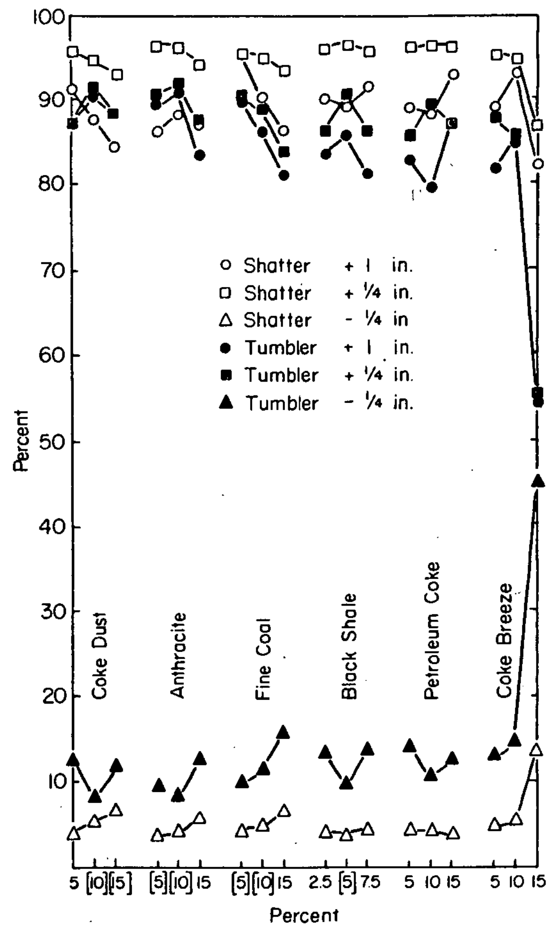
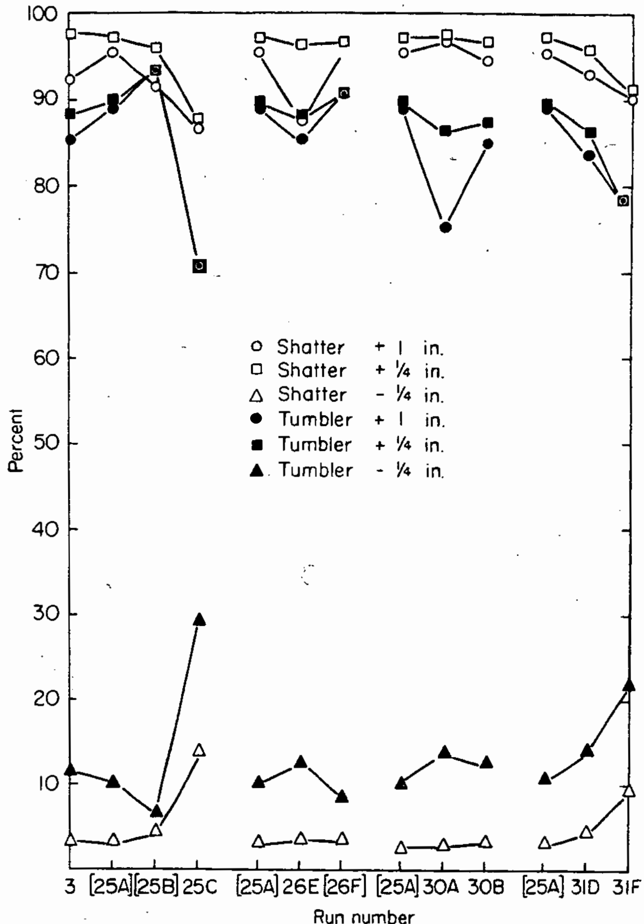


Fig. 4. - Comparison of coke character and the amount of minus 20 mesh material used in blends of different additives.



Run	Coal, % No. 6	No. 5	Additives	%	Others	%
3	70	30				
25A	70	30			"Resin"	5
25B	63	27	Fusain (-150M)	10	"Resin"	5
25C	56	24	Fusain (-150M)	20	"Resin"	5
26E	63	27	Anthracite (-20M)	10	"Resin"	5
26F	56	24	Anthracite (-20M)	20	"Resin"	5
30A	63	27	Petroleum Coke (-10M)	10	"Resin"	5
30B	56	24	Petroleum Coke (-10M)	20	"Resin"	5
31D	63	27	Coke Dust (-20M)	10	"Resin"	5
31F	63	27	Fusain (-150M)	10	Coal Tar	5

Fig. 5. - Character of coke produced by blends containing five percent "resin" and various amounts of high carbon components.

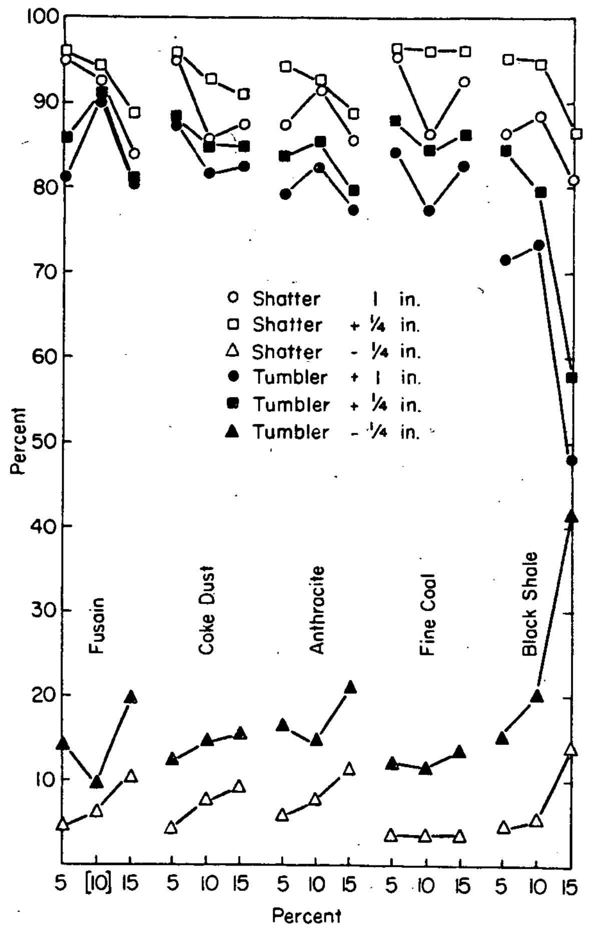
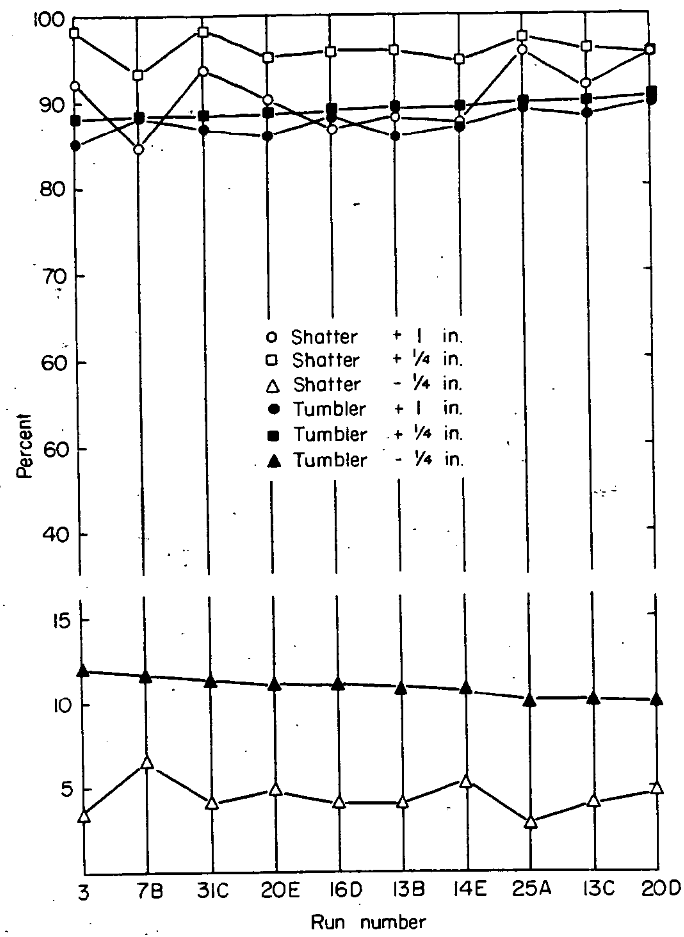
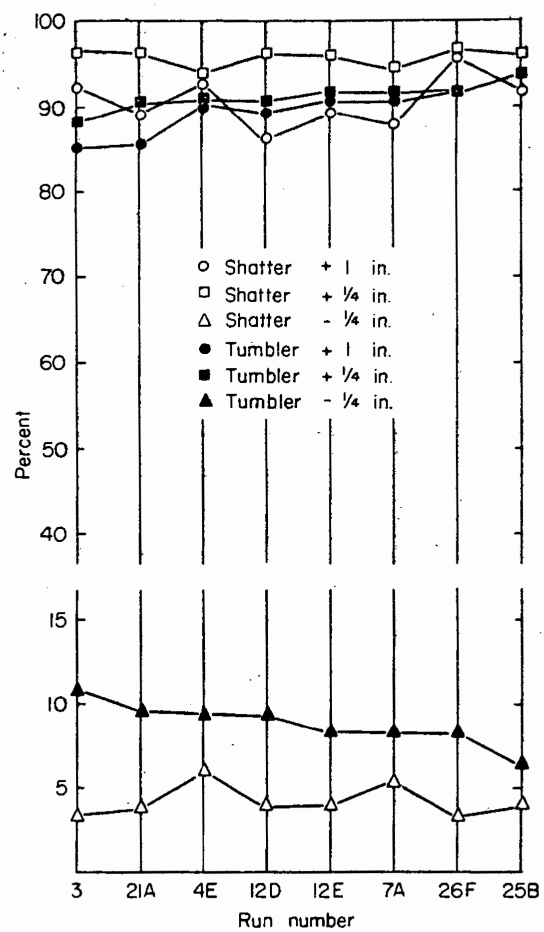


Fig. 6. - Comparison of coke character and the amount of the minus 150 mesh material used in blends of different additives.



Run	Coal, % No. 6	No. 5	Additives	%	Others	%
3	70	30				
7B	59.5	25.5	Coke Dust (-20M)	15		
31F	63	27	Fusain (-150M)	10	Coal Tar	5
20E	63	27	"Fine Coal" (-20M)	10		
16D	66.5	28.5	Petroleum Coke (-10M)	5		
13B	66.5	28.5	Anthracite (-10M)	5		
14E	56	24	Anthracite (-10M)	20		
25A	70	30			"Resin",	5
13C	63	27	Anthracite (-10M)	10		
20D	66.5	28.5	"Fine Coal" (-20M)	5		

Fig. 7. - Coke character produced by various sizes and amounts of different additives. All cokes are superior to those produced from "standard blend" alone.



Run	Coal, % No. 6	Coal, % No. 5	Additives	%	Others	%
3	70	30				
21A	66.5	28.5	Black Shale (-20M)	5		
4E	63	27	Fusain (-150M)	10		
12D	66.5	28.5	Anthracite (-20M)	5		
12E	63	27	Anthracite (-20M)	10		
7A	63	27	Coke Dust (-20M)	10		
26F	56	24	Anthracite (-20M)	20	"Resin"	5
25B	63	27	Fusain (-150M)	10	"Resin"	5

Fig. 8. - Coke character produced by various sizes and amounts of different additives. All cokes are superior to those produced from "standard blend" alone.